Summary

Horizontal subsurface flow constructed wetlands (HSSF CWs) are being considered in South Africa as an alternative waste water treatment technology which is low in capital costs and typically requires less operational infrastructure when compared to conventional treatment technologies. HSSF CWs may thus be a potential solution for solving the challenge of ensuring reliable access to clean water for rural communities whose municipalities may not be able to afford the construction of a waste water treatment plant as well as not being able to supply sufficient technical expertise for the operation thereof. Proper design of HSSF CWs requires a detailed investigation into the hydraulic behaviour as it has a direct effect on the treatment performance in these systems.

In this study, three available hydraulic modelling methodologies for HSSF CWs were compared and these are the impulse, step change integral and step change derivative modelling methodologies. Hydraulic data were generated from planted and unplanted pilot scale HSSF CWs using residence time distribution (RTD) studies and the modelling results using each methodology were compared. It was found that each methodology was capable of suggesting a different hydraulic behaviour for the same system being studied and since it is not possible to evaluate an analytical answer to the problem independently it was not possible to determine which modelling methodology was the most accurate. Practical limitations of the experiments used to feed hydraulic data to the respective methodologies were also highlighted. Despite a well-designed sampling regime it was not possible to capture sufficient data surrounding the peak of the impulse response curve and may have impacted negatively on the modelling results. No such difficulties were encountered with the step change tracer experiments. The mathematical techniques which each methodology employs were also critically assessed. It was found that numerical differentiation in the step change derivative modelling approach introduced noise into the RTD curve and may have affected subsequent results. Ultimately each methodology has its own associated strengths and weaknesses and choice of methodology may be dictated by other factors such as cost to set up the hydraulic experiment as well as equipment availability.

Tasks two and three of this dissertation dealt with how Biomimicry can be used as a tool to develop more sustainable HSSF CW designs and hydraulic modelling processes. In task two, hydraulic data generated from the first task were used to develop estimates of the velocity profiles inside a planted HSSF CW to identify regions most prone to clogging, a phenomenon

which would be a serious concern for rural communities whose sole water treatment system would be the CW. Biomimetic design principles were combined with the modelling results to develop a modular system design allowing for sections of the CW to be removed for cleaning while still allowing for continuous treatment of the waste water.

Task three explored the use of heat as a hydraulic tracer. Heat is considered more environmentally friendly when compared to chemicals as tracers as the CW can equilibrate to ambient conditions post study and the effluent does not require dedicated disposal infrastructure. Heat is non-conservative in these systems and processes such as absorption by the subsurface media and loss to the surroundings distort the hydraulic response curve from which the hydraulic behaviour cannot be directly obtained. In this study a mathematical model was developed which maps a heat tracer response curve to one which would be obtained if a conservative chemical tracer were used. It was tested by conducting a combined heat-chemical tracer study on an unplanted laboratory-scale HSSF CW and the predicted chemical response curve was compared with the actual experimental response curve. The model performed satisfactorily indicated by a 5% and 6% relative difference in the Peclet number (Pe) and mean of the RTD respectively. In each of these chapters, an abstract is provided which summarizes the main findings of the study.